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Six new non-native turtles in Portugal: A growing threat apart from the Red-Eared slider and Chinese stripe-necked turtle

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Abstract

We report the first records of non-native freshwater turtles in Portugal, highlighting the growing diversity of species introduced in addition to the known *Trachemys scripta* and *Mauremys sinensis*. In 2024 and 2025, we surveyed 39 sites across Portugal and confirmed the presence of seven non-native species at seven sites. While *T. scripta* remained the most frequently recorded species (n = 68), *M. sinensis*, *Graptemys pseudogeographica* and different species of *Pseudemys*, were also captured, especially in Lisbon and Sintra. Remarkably, a high number of *M. sinensis* juveniles (n = 12) were captured, which could be explained by reproduction in nature. Notably, we documented the first evidence of nesting behaviour by *G. pseudogeographica* in Sintra, indicating the potential for this species' establishment in the wild. These findings suggest that both illegal and legal non-native turtle pets are being released into Portuguese ecosystems. Our results highlight the need for broader preventative measures, as other introduced species may follow similar invasion pathways with unknown ecological impacts.

Key Words

Alien species, *Mauremys sinensis*, *Graptemys pseudogeographica*, introductions, nesting, pet trade

Introduction

Portugal hosts two native freshwater turtle species, *Emys orbicularis* (Linnaeus, 1758) (European pond turtle) and *Mauremys leprosa* (Schweigger, 1812) (Mediterranean pond turtle), both of which play an important ecological role in aquatic ecosystems. These native species are particularly vulnerable to habitat degradation, pollution and competition with introduced turtles, making the presence of invasive species a significant conservation concern (Polo-Cavia et al. 2014; Franch et al. 2022). One of these species, *Trachemys scripta* (Schoepff, 1792), is the most introduced and widespread turtle species in the world, earning its inclusion amongst the world's 100 worst invasive species (Lowe et al. 2000), due to its ecological generalism, high mobility, brumation capacity, early sexual maturation and high fecundity (Semenov 2010).

There have been several reports of negative impacts associated with *T. scripta* on other wildlife, including – but not limited to – predation (Cuthbert 2019), competition (Polo-Cavia et al. 2014) and disease transmission (Héritier et al. 2017). Interactions with native turtles, such as *E. orbicularis*, have been shown to cause declines in body condition and even increased mortality (Cadi

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and Joly 2004). Additionally, *T. scripta*, kept as pets, are known to be a source of zoonotic diseases, such as *Salmonella* spp. (Basler et al. 2015).

To stop *T. scripta* and other species invasion, the European Union (EU) adopted Regulation (EU) 1143/2014 and, subsequently, the Commission Implementing Regulation (EU) 2016/1141, which blacklists several invasive species of particular concern in the EU. This blacklist prohibits the trade, breeding and release of *T. scripta*. However, following this blacklisting, several other turtle species began to be traded more widely (Sancho et al. 2020; Rato et al. 2024).

Masin et al. (2014) demonstrated that several species of freshwater turtles (*Apalone ferox*, *Apalone spinifera*, *Graptemys kohnii*, *Pseudemys concinna*, *Pseudemys floridana*, *Pseudemys nelsoni*, *Kinosternon baurii*, *Kinosternon subrubrum*, *Sternotherus carinatus*, *Sternotherus odoratus*, *Pelomedusa subrufa*, *Pelodiscus sinensis*, *Mauremys reevesii*, *Mauremys sinensis*) possess attributes similar to *T. scripta* and that the risk of their establishment in Europe ranges from high to extreme. This is particularly concerning because many of these species are already present in Europe (Rato et al. 2025a). Other species are considered to have a moderate invasion risk, such as *Mauremys sinensis* (Gray, 1834) (Rato et al. 2024), as well as species with a high invasion risk, such as *Graptemys pseudogeographica* (Gray, 1831) and *Pelomedusa subrufa* (Lacépède, 1788) (Masin et al. 2014; Foglini 2021).

As *Trachemys scripta* trade is restricted by European legislation, this has led to a shift in the turtle pet market, with replacement by other non-native turtle species. As a result, national blacklists have incorporated some other non-native turtle species with the aim of preventing further introductions. For example, Portugal enacted Decreto-Lei no. 92/2019, the Portuguese blacklist published in 2019, which bans the trade of six taxa: *T. scripta*, *Graptemys* spp., *Pseudemys* spp., *Chrysemys picta*, *Macrochelys temminckii* and *Chelydra serpentina*. However, the free movement of people and goods within the Schengen Area, which covers a large part of Europe hinders the enforcement of the blacklists (Rato et al. 2025a).

Herein, we report the first records of non-native turtles in Portugal, in addition to the previously recorded *T. scripta* and *M. sinensis* (Martins et al. 2018; Anastácio et al. 2019; Rato et al. 2024).

In 2024 and 2025, during fieldwork on herpetological projects – including non-native turtle control and eradication initiatives funded by the Portuguese Environmental Fund – we sampled 39 sites. Thirty-five sites were located south of the Tagus River, with only four sites north of the river (Fig. 1). Turtles were captured using dip nets in public spaces and minnow/fyke traps (both baited with sardines) equipped with floaters or basking traps in natural or semi-natural areas.

Turtle species were identified, based on external morphological characteristics following the diagnostic criteria described by Pleguezuelos et al. (2002), Fritz (2003) and Sousa et al. (2019). For each turtle, we measured straight carapace length (SCL), straight carapace width (SCW) (measured at the widest point), carapace height (CH) (measured in the highest point) and weight. Measurements were taken using calipers for measures, recorded in centimetres with a precision of 0.01 cm and a scale for weight, recorded in kilograms with a precision of 0.005 kg. The body condition index (BCI) was calculated using $\left[\frac{\text{Weight}}{(\text{SCL} \times \text{SCW} \times \text{CH})} \times 10000\right]$ as weight divided

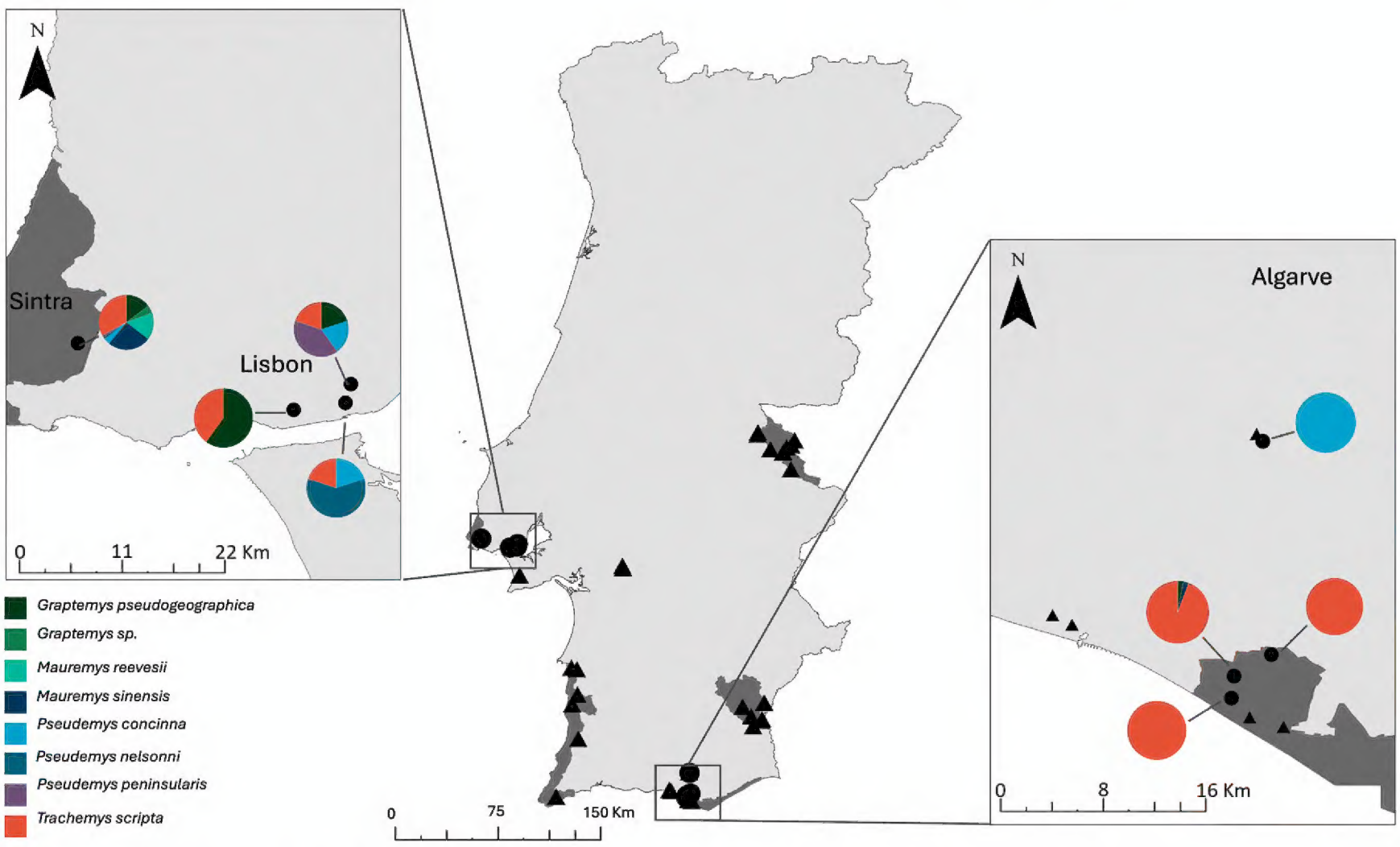

Figure 1. Sampling sites included in this study. Triangles – sites with only native species. Circles – sites where non-native turtle species were recorded. The relative frequency of each recorded non-native species is presented for each site.

by volume, with volume estimated by multiplying SCL, SCW and CH. The result was then multiplied by 10,000 to improve readability. Sex determination was based on secondary sexual characteristics, including tail length and claw size on the fore-limbs, with males exhibiting longer tails and elongated claws compared to females; in the absence of clear external features, individuals were classified as juveniles (Readel et al. 2008; Ayres 2014).

For the species present in all sites, differences in size, weight and body condition were analysed using the Kruskal–Wallis test and differences in sex ratios were tested using the Chi-squared test, both conducted in RStudio 2025.05.1+513 (Posit team 2025).

We captured non-native turtles at seven out of the 39 sampled sites: three sites in public gardens in Lisbon (semi-natural ecosystems; concrete ponds), one site in Sintra's Natural Park (natural ecosystems, lakes) and four sites in two protected areas in the Algarve (natural ecosystems, lakes). In total, seven non-native turtles' species were identified (*Graptemys pseudogeographica*, *Mauremys reevesii*, *Mauremys sinensis*, *Pseudemys concinna*, *Pseudemys nelsoni*, *Pseudemys peninsularis*, *Trachemys scripta*), with 137 individuals captured (Table 1). Individual records are provided in Suppl. material 1.

Overall, *Trachemys scripta* was the most frequently recorded species in Portugal (n = 68), followed by *Mauremys sinensis* (n = 22) and *Graptemys pseudogeographica* (n = 17). In Sintra, one female *G. pseudogeographica* was captured by hand during nesting digging activity. The four individuals of *Graptemys* sp. could not be identified to species level, due to the lack of typical characteristics of *G. pseudogeographica*. In the Algarve, the non-native turtle community was dominated by *T. scripta*, with the remaining species represented by only three records (Fig. 1). In contrast, in Lisbon and Sintra, other species had considerably more records compared to the Algarve (Fig. 1). Nevertheless, *T. scripta* remained the most frequently recorded species in all areas (Fig. 1). The diversity of the non-native turtle communities differed significantly amongst regions ($\chi^2 = 79.891$, $p < 0.05$). The diversity of non-invasive species recorded in this study was higher in Lisbon than in the Algarve, which is consistent with the findings of Rato et al. (2025b). This pattern is likely related to the greater availability of species in the pet trade and the higher human population density in Lisbon (Rato et al. 2025b).

Biometric measurements are presented in Table 1. The only two species recorded in all areas – *G. pseudogeographica* and *T. scripta* – showed similar size. weight and sex ratios, demonstrating similar invasion success across the country. However, the body condition index differed significantly between *T. scripta* populations in Lisbon and Algarve ($\chi^2 = 8.5284$, $p = 0.01406$). These differences could be related to the type of ecosystem – semi-natural (Lisbon) and natural (Algarve) – and the food availability at each site. In the case of Lisbon, in semi-natural ponds located in public gardens, turtles were regularly fed by people (pers. observation), whereas in the Algarve, turtles fed on naturally available resources. Consequently, better body condition indices were observed in Lisbon compared to the Algarve. Moreover, a notably higher number of female *T. scripta* were recorded compared to males in all sites (Table 1). It is also noteworthy that, as 12 juveniles of *Mauremys sinensis* were found in Sintra, this could by the first evidence of these species reproduction in the wild in Portugal.

The time lag of 3 years between the establishment of the Union's list of invasive alien species and its incorporation

Table 1. Average biometric measurements and female, male and juvenile diversity for each sampled sites. Algarve includes four sampling sites; Lisbon includes three sampling sites and Sintra includes one sampling site. n – number of turtles, SCL – Straight carapace length in centimetres, SCW – Straight carapace width in centimetres, CH – Carapace height in centimetres, weight in kilograms, BCI – Body condition index, F- Female, M- Male, J- Juvenile. Turtles were sexed, based on external morphological characteristics.

Site/Species	n	SCL (SD/Min-Max)	SCW (SD/Min-Max)	CH (SD/Min-Max)	Weight (SD/Min-Max)	BCI (SD/Min-Max)	F	M	J
Algarve	33						28	9	3
G. pseudogeographica	1	14.36	11.05	4.76	0.32	4.24	0	1	0
M. sinensis	1	9.84	6.81	3.39	0.12	5.28	0	1	0
P. concinna	1	12.49	9.23	5.42	0.30	4.80	1	0	0
T. scripta	37	16.15 (3.99/3.68–21.9)	12.71 (2.91/3.55–16.65)	6.43 (1.67/1.52–10.28)	0.74 (0.396/0.01–1.69)	4.92 (0.314/4.12–5.52)	27	7	3
Lisbon	14						7	6	1
G. pseudogeographica	4	10.5 (2.02/7.9–12.20)	8.65 (1.22/6.85–9.47)	4.27 (1.13/3.20–5.40)	0.21 (0.123/0.07–0.33)	4.91 (0.789/3.80–5.60)	1	1	2
P. concinna	2	16.23 (2.86/14.20–18.25)	12.20 (1.56/11.10–13.30)	5.40 (0.42/5.10–5.70)	0.70 (0.286/0.49–0.90)	6.33 (0.245/6.16–6.51)	1	1	0
P. nelsoni	3	21.08 (4.33/16.30–24.75)	15.77 (2.15/13.40–17.60)	7.88 (0.94/6.80–8.45)	1.49 (0.671/0.72–1.95)	5.36 (0.539/4.85–5.92)	1	2	0
P. peninsularis	2	16.45 (2.47/14.70–18.20)	13.90 (2.12/12.40–15.40)	5.70 (1.56/4.60–6.80)	0.98 (0.237/0.82–1.15)	7.88 (2.61/6.03–9.72)	1	1	0
T. scripta	4	18.36 (2.06/15.85–20.10)	13.96 (1.30/12.25–15.20)	6.83 (1.11/5.40–7.82)	1.01 (0.309/0.56–1.27)	5.63 (0.368/5.32–6.09)	3	1	0
Sintra	82						45	19	18
G. pseudogeographica	12	13.54 (2.50/9.10–17.55)	10.97 (1.97/7.45–13.65)	5.06 (0.98/3.50–6.40)	0.36 (0.20/0.11–0.78)	4.41 (0.54/3.52–5.16)	6	5	1
Graptemys sp.	4	14.25 (1.80/12.40–16.70)	11.23 (1.20/10.00–12.80)	5.10 (0.76/4.60–6.20)	0.37 (0.12/0.28–0.55)	4.53 (0.44/4.11–5.05)	3	1	0
M. reevesii	13	10.66 (2.25/7.50–15.30)	14.9 (2.65/5.30–16.00)	4.66 (1.06/3.20–6.90)	0.23 (0.14/0.07–0.62)	5.17 (1.55/0.55–7.20)	5	4	4
M. sinensis	21	10.69 (2.54/6.20–18.50)	7.87 (1.78/4.60–13.90)	4.35 (0.93/2.70–7.30)	0.22 (0.20/0.06–1.04)	5.29 (0.69/4.45–7.14)	3	6	12
P. concinna	3	13.70 (1.65/12.70–15.60)	11.12 (1.10/10.00–12.20)	5.40 (1.55/3.80–6.90)	0.43 (0.16/0.28–0.59)	5.20 (0.63/4.49–5.70)	2	1	0
P. nelsoni	1	17.60	14.00	6.40	0.61	3.84	1	0	0
P. peninsularis	1	10.85	8.80	5.60	0.23	4.30	1	0	0
T. scripta	27	16.48 (3.33/7.50–21.50)	13.16 (2.83/6.70–18.50)	6.93 (1.76/3.00–9.50)	0.89 (0.53/0.09–0.187)	5.15 (0.99/3.30–8.81)	24	2	1

into Portuguese legislation allowed for the continued trade of species that would later be prohibited. Nevertheless, some banned taxa are still available for purchase, particularly through social media platforms (Rato et al. 2025a). Although these turtles are often not released immediately after purchase – typically being kept until they become too large for private care (Banha et al. 2019) – our findings suggest that all reported species have entered the second stage of the invasion process (Colautti and MacIsaac 2004).

Additionally, we report the observation of tentative nesting by *G. pseudogeographica* – a species prohibited to be sold in Portugal – which indicates its potential for establishment and suggests it may be reaching the third stage of the invasion process (establishment) (Colautti and MacIsaac 2004). Furthermore, several species currently available for legal sale, such as *M. sinensis* and *M. reevesii*, also pose invasion risks (Masin et al. 2014) leading to additional impacts not previously associated with *T. scripta*, such as potential hybridisation with native turtles – in the case of *Mauremys* spp. (Sancho et al. 2020) – and the introduction of new diseases (Martínez-Silvestre et al. 2015).

Considering both the documented invasion risks (Masin et al. 2014) and future climate suitability (Banha et al. 2017), Europe – particularly Portugal – may face significant challenges related to non-native turtle introductions, even if currently established species are banned from trade. Prohibiting trade in specific species often leads to their replacement by other taxa, potentially making a white-list approach (Simberloff 2006) a more effective regulatory framework. However, the development of such positive lists must be preceded by rigorous risk assessments to ensure that only species with minimal risks of invasion or welfare are permitted (Toland et al. 2020). Furthermore, the effectiveness of any listing system ultimately depends on its proper implementation and enforcement, comprising both clear regulatory mechanisms and monitoring as well as sanctions for non-fulfilment.

Although *T. scripta* remains the most prevalent non-native turtle in Portugal – and globally – several other species have also been introduced, though they may still be at earlier invasion stages. In some cases, such as with *Graptemys* spp. and *Pseudemys* spp., trade has already been prohibited, but natural reproduction may still increase their populations, complicating control efforts and raising potential economic costs (Roy et al. 2024). In other cases, like *Mauremys* spp., no legal measures currently prevent their trade despite their ecological risks. However, in Spain, the genus *Mauremys* has recently been included in the Spanish Catalogue of Invasive Alien Species due to the risk of hybridisation with the native *Mauremys leprosa* (Orden TED/452/2025, de 5 de mayo).

This study emphasises the urgent need to control not only well-established invasive species like *T. scripta*, but also emerging invaders, such as *Graptemys* spp. and *Mauremys* spp., before they become further entrenched. Finally, closer cooperation between the scientific community and policy-makers would be invaluable in enhancing coordinated efforts to prevent and control non-native turtle invasions.

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Supplementary material 1

Supplementary table

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Data type: xlsx

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